CLASSIFICATION OF SMALL NEGATIVE LIGHTNING REPORTS AT THE KSC-ER

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Introduction

The NASA Kennedy Space Center (KSC) and Air Force Eastern Range (ER) operate an extensive suite of lightning sensors because Florida experiences the highest area density of ground strikes in the United States, with area densities approaching 16 fl/km^2/yr when accumulated in 10x10 km (100 km^2) grids. The KSC-ER use data derived from two cloud-to-ground (CG) lightning detection networks, the "Cloud-to-Ground Lightning Surveillance System" (CGLSS) and the U.S. National Lightning Detection Network™ (NLDN) plus a 3-dimensional lightning mapping system, the Lightning Detection and Ranging (LDAR) system, to provide warnings for ground operations and to insure mission safety during space launches.

For operational applications at the KSC-ER it is important to understand the performance of each lightning detection system in considerable detail. In this work we examine a specific subset of the CGLSS stroke reports that have low values of the negative inferred peak current, Ip, i.e. values between 0 and -7 kA, and were thought to produce a new ground contact (NGC). When possible, the NLDN and LDAR systems were used to validate the CGLSS classification and to determine how many of these reported strokes were first strokes, subsequent strokes in a pre-existing channel (PEC), or cloud pulses that the CGLSS mis-classified as CG strokes.

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It is scientifically important to determine the smallest current that can reach the ground either in the form of a first stroke or by way of a subsequent stroke that creates a new ground contact. In Biagi et al (2007), 52 low amplitude, negative return strokes (|Ip| ≤10 kA) were evaluated in southern Arizona, northern Texas, and southern Oklahoma. The authors found that 50-87% of the small NLDN reports could be classified as CG (either first or subsequent strokes) on the basis of video and waveform recordings. Low amplitude return strokes are interesting because they are usually difficult to detect, and they are thought to bypass conventional lightning protection that relies on a sufficient attractive radius to prevent "shielding failure" (Golde, 1977). They also have larger location errors compared to the larger current events. In this study, we use the estimated peak current provided by the CGLSS and the results of our classification to determine the minimum Ip for each category of CG stroke and its probability of occurrence. Where possible, these results are compared to the findings in the literature.

Instrumentation

The CGLSS covers the operational area of the KSC-ER with six IMPACT ES lightning sensors[4] placed 10 to 30 km apart (see Figure 1). The CGLSS system operates in the following manner: 1) sensors detect the electromagnetic pulse produced by a lightning stroke to ground; 2) data on the time, amplitude, polarity, and direction are sent via land-line communications to a central position analyzer for processing; 3) data from multiple sensors are processed to provide the time, location, polarity, and an inferred peak current for each stroke are sent to the network display system. The CGLSS sensor locations are shown in Figure 1 (black triangles).

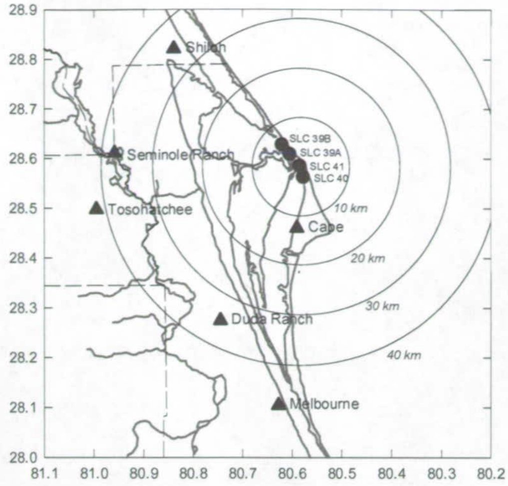

Figure 1. Locations of the CGLSS sensors (triangles) at the KSC-ER in 2006.

The NLDN is a national network that contains 113 Vaisala IMPACT sensors placed 200 to 350 km apart. Figure 2 shows the region of the KSC-ER and its location relative to the 10 nearest NLDN sensors. The three closest sensors to the KSC-ER are located in Palm Bay, FL, Tampa, FL, and Ocala, FL. The NLDN system operates in the following manner: 1) sensors detect the electromagnetic pulse produced by a lightning stroke to ground; 2) data on the time, amplitude, polarity, and direction are sent via satellite communications to a network control center in Tucson, Arizona; 3) the data provided by multiple sensors are processed to locate the event and determine its time-of-occurrence, an inferred peak current, and its polarity (Cummins et al, 2006); 4) processed data are forwarded to users in real-time via either terrestrial or satellite data links (Cummins et al, 1998).

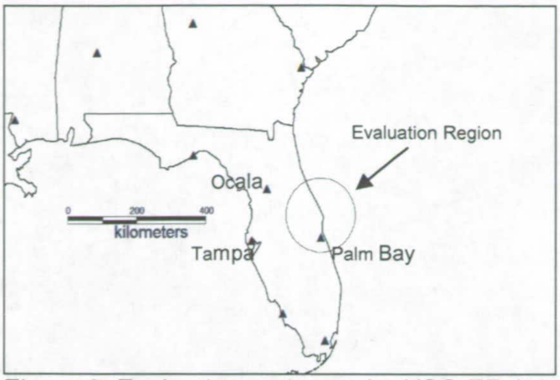

Figure 2. Evaluation region at the KSC-ER (100 km radius) and the locations of the nearest NLDN sensors.

The NLDN and CGLSS systems differ somewhat in their processing of lightning information. Currently, the NLDN locates all detected strokes, optionally groups them into flashes, and estimates the Ip for each stroke by scaling the range-normalized signal strength by a factor of 0.185 (Cummins et al., 2006). The reported time is the estimated time-of-occurrence of the stroke. The CGLSS on the other hand, locates the first stroke in each flash and a fraction of the subsequent strokes that have strike locations more than 0.5 km from the first-stroke location (Maier and Wilson, 1996). In the following text, we refer to both of these types of events as CGLSS strokes. It then computes an inferred peak current (Ip) by scaling the range-normalized signal strength by a factor of 0.23. The CGLSS event time is the time that the field waveform exceeds a fixed detection threshold at the nearest reporting sensor. This time can be up to 200 μs after the time-of-occurrence of the NLDN strokes in the evaluation region. When more than one stroke is detected at the same strike point, the CGLSS reports the highest Ip in any stroke.

The LDAR system is a volumetric lightning mapping system that consists of 7 time-of arrival (TOA) receivers spaced about 10 km radially from a central site. Figure 3 shows the location of the central site (yellow) and the six remote sensors (red). The LDAR system has a range of about 100 km and a location accuracy of about 100m within 3 km of the central site. The LDAR sensors detect VHF pulses in a 6 MHz bandwidth centered at 66 MHz which are thought to be produced by lightning stepped-

leaders and other breakdown processes. The antennas are equally as sensitive to both horizontal and vertical polarized signals. LDAR has a flash detection capability that is close to 100% and a false alarm rate below 1% (Maier et al, 1995). For a more detailed description of the LDAR system see Lennon and Maier (1991), Maier et al. (1995), and Boccippio et al. (2000a,b).

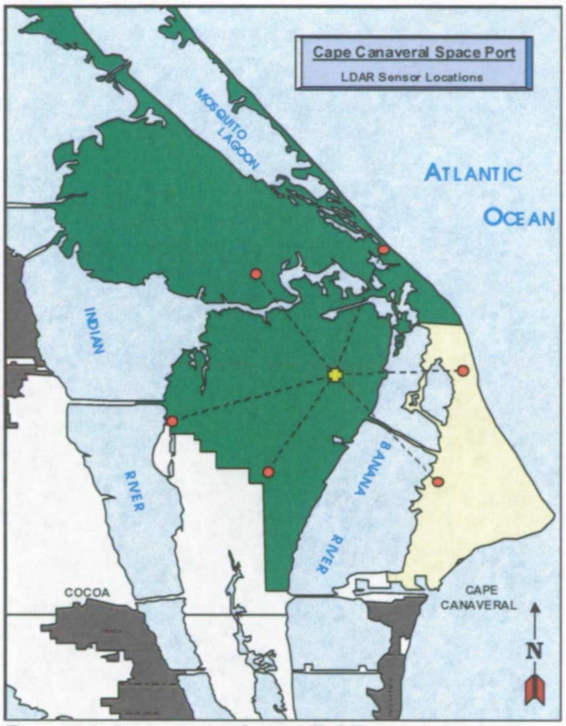

Figure 3. Location of the LDAR sensors and central station at the KSC-ER.

While refining our method of classification using LDAR data, time-correlated broadband electric field waveforms recoded by the Los Alamos Sferic Array (LASA) in central Florida were employed for independent validation. LASA records electromagnetic pulses from lightning in support of radio frequency (RF) and optical observations by the Fast On-orbit Recording of Transient Events (FORTE) satellite (Smith et al., 2002, Shao et al., 2006)). The Florida array consists of eight stations that are connected to the internet, and the operation, data retrieval, and data processing is done through the internet from Los Alamos (Shao et al., 2006). For this study, the closest LASA stations were located at Daytona Beach, FL, Tampa, FL, and Jacksonville, FL. Of the three Florida sites, only Tampa was operational during the summer of 2006. The Tampa site is located about 200km from the KSC-ER, and because of this large distance, many of the smaller CGLSS strokes were below the detection threshold (~ 0.5 V/m) of the Tampa sensor.

Methods

Data and Event Selection Process

The CGLSS data were processed by Computer Sciences Raytheon and delivered in a standard APA output form. It was then reformatted to display only relevant stroke data information needed for LDAR and NLDN comparisons. The data fields consisted of date, time in ms, latitude and longitude in degrees, multiplicity (number of strokes in the flash), peak current (kA), chi-squared value, and semi-major and semi-minor axis (nm) values. The chi-squared value is a normalized measure of "agreement" among the reporting sensors. Ideally, the chi-squared distribution has mean and median values equal to one. Chi-square values between 0 and 3 are considered to be "good"; values between 3 and 10 are "acceptable." The semi-major and semi-minor axes values characterize the confidence region for a given probability value, based on a two-dimensional (spatial) Gaussian distribution of location errors inferred from knowledge of the measurements errors and the placement of the sensors used in the location calculation (see Vaisala Technical Note, 2004 for further details). The probability value for CGLSS is associated with the one-standard-deviation location error (P = 0.39).

The NLDN data were provided by Vaisala Inc. in Tucson AZ. Data consisted of date, time in ms, latitude and longitude in degrees, peak current (kA), error-ellipse semi-major axis (km), chi-squared value, and the number of sensors reporting the stroke (NSR) . The ellipse probability value for the NLDN is associated with the median location error (P = 0.50)

The raw binary LDAR data were provided by the KSC and then reprocessed into text form by Vaisala Inc. The data consisted of the date and

time, latitude and longitude, and height of the vhf sources in meters.

All lightning events reported by the CGLSS in the summer of 2006 (June 1 to August 31) were examined and then all the negative strokes that were within 20 km of an origin at the LDAR central site (see Figure 3) were entered into a spreadsheet. Next, all events that had a low amplitude (|Ip|< 7kA) and were separated from any previous CGLSS stroke by more than 0.5 seconds in time or 2 km in space were selected for further analysis. Using these criteria, a total of 237 low amplitude "candidate" first strokes were detected out of 4967 lightning flashes. Within this sample of low amplitude strokes, 114 were detected by at least two of the three lightning detection systems (CGLSS, NLDN, and LDAR), and these events were analyzed in greater detail.

Figure 4 (Ward et al., 2008 - Figure 5) is a scattergram showing the relationship between the NLDN Ip (x-axis) and CGLSS Ip (y-axis) for 3294 time-correlated strokes that were detected on July 23, 2006. This figure also shows the linear regression (slope = 1.11, with zero intercept) and R^2 value (0.90). Note that the NLDN and CGLSS Ip values are highly correlated over the range of - 150 kA to + 150 kA, and that the largest scatter is for the extreme values of Ip (maximum and minimum). On average, the CGLSS Ip values are slightly higher than the NLDN values. This difference was expected because the systems used different scaling factors to convert the peak field that was measured to peak current (0.23 for CGLSS; 0.185 for NLDN). This scaling difference predicts a slope of 1.23 (0.23/0.185), which is within 10% of the empirically-derived slope. The remaining difference is likely associated with limitation in the propagation models (Cummins et al, 1998), since the propagation paths to NLDN sensors are roughly 2-3 times longer than for the CGLSS sensors.

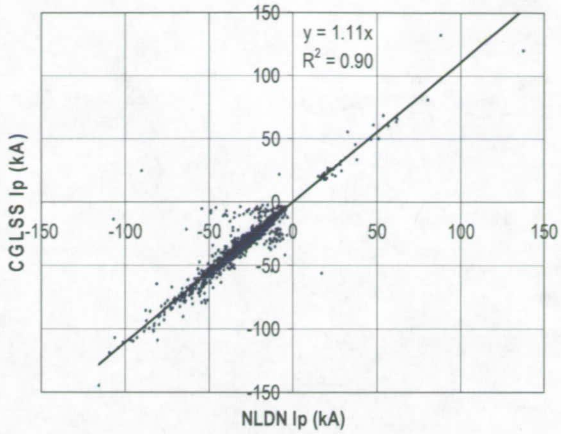

Figure 4. CGLSS Ip values vs. NLDN Ip values for 3294 lightning strokes that were reported on July 23, 2006.

Figure 5 is a scattergram showing the relationship between the NLDN Ip (x-axis) and CGLSS Ip (y-axis) for the 67 time-correlated, negative low amplitude strokes with |Ip|<7kA in our dataset. Here, a correlation factor of 1.13 has been applied to the CGLSS Ip values to correct for the scaling difference. This figure also shows the linear regression (slope = 0.94, with zero intercept) and R^2 value (0.52).

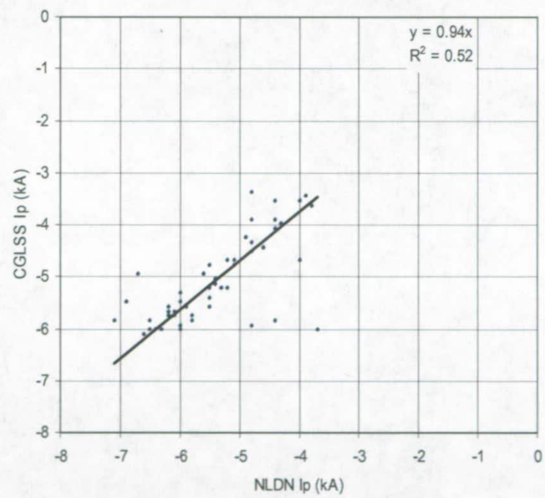

Figure 5. CGLSS Ip values vs. NLDN Ip values for the 67negative low amplitude strokes, |Ip|<7kA in our dataset that were reported by both networks.

Data Processing

In order to find coincident events between the CGLSS and LDAR datasets, a one-second interval of data that included each CGLSS event was plotted as a function of time as shown in Figure 6a. Here and in figures 7a to 10a to follow, the blue dots show the altitudes and times of the LDAR sources and the colored squares show the times that the CGLSS and NLDN systems reported strokes. A total of one second of data were plotted because an entire lightning flash is usually less than one second in duration (McNamara, 2002). Progression of the stepped leader towards ground characterized by a "line" of LDAR sources moving from higher to lower altitudes, shown preceding the two CGLSS strokes in Figure 6a. Larger strokes usually have a better-defined line of sources moving toward the ground, and smaller strokes may only have one or two sources at low altitudes. The remaining LDAR sources are associated with branches or channel development inside the cloud. The CGLSS stroke-of-interest (SoI) in this case is shown as a red square at a height of 0 m. Any other CGLSS or NLDN strokes in the interval of interest, and within a distance of 20 km, are also shown in the plot with the labeled symbols. If the NLDN recorded the SoI, that event is plotted as an asterisk directly above the CGLSS event at 2000 m. Figure 6a is an example of a LDAR, CGLSS and NLDN record for a -3.5 kA subsequent stroke that produced a new ground contact at 18:54:36.6370 UTC on July 7, 2006.

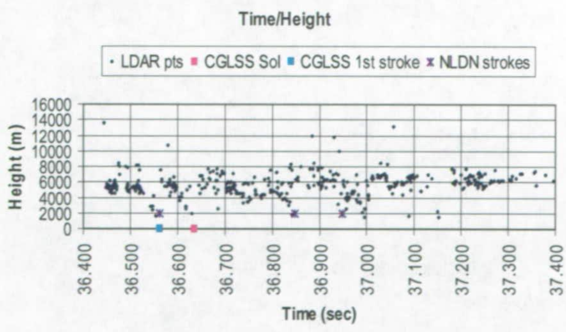

Figure 6a. Heights of LDAR sources as a function of time for a subsequent stroke that that produced a new ground contact on July 7, 2006 at 18:54:36.6370 UTC with an Ip of -3.5 kA.

Figure 6b shows a plan view of the LDAR sources and strokes shown in Figure 6a. Note that the SoI was located approximately 9 km southwest of the first stroke, and that the 3rd and 4th strokes located by the NLDN are much closer to the location of the first stroke. This is a typical pattern for a multi-stroke negative flash, where the second stroke can be located some distance from the first stroke, and later strokes occur in or near the channel established by the first stroke (Valine and Krider, 2002).

Two aspects of Figures 6 indicate that the SoI is a subsequent stroke producing a new ground contact. Figure 6a shows evidence of a stepped leader progression just prior to the return stroke at 18:54:36.637 UTC. This is supported by the large spatial separation between the SoI and all other strokes shown in Figure 6b. In a case such as this, knowledge of the expected location error derived from the error ellipse parameters is used to determine if the location difference between strokes could be explained by random location error.

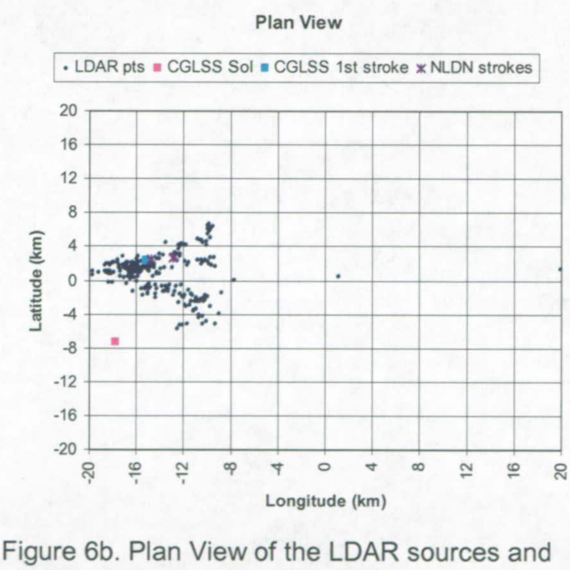

Figure 6b. Plan View of the LDAR sources and strokes shown in Figure 6a.

Figure 6c shows the LASA electric field waveform from the Tampa site (circled) that was associated with the SoI. On careful examination, this waveform had the attributes of a return stroke that established a new ground contact. This supports the LDAR-based assessment that the SoI is associated with a new ground contact.

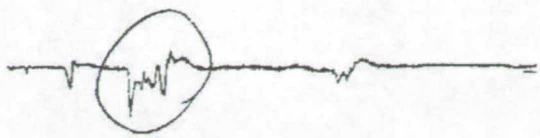

Figure 6c. The LASA waveform for the -3.5 kA subsequent stroke that produced a new ground contact shown in figures 6a and b.

This approach to stroke classification was refined and tested for several flashes that had accompanying LASA waveforms, in order to gain confidence that proper classification could be made without the aid of the LASA waveforms (for low-current events that were not detected by LASA)

Results

Classification

A table of all the small CGLSS strokes that were analyzed in detail and their final classifications can be found in Appendix A. Representative examples of each of the four classes are discussed in detail in this section.

18 percent (21 strokes) of the strokes in our dataset were determined to be first strokes. Characteristics of the storm cells (growing, developed, or decaying) that were associated with all 21 first strokes were tabulated and compared to determine if there was a tendency for small storms to produce small strokes, and none was found. 10 events were associated with large, well developed storms and 11 were in small, developing or decaying cells.

Figure 7 depicts a -4.4kA first stroke that occurred on July 17, 2006 at 19:46:53.9177 UTC. The time/height plot in Figure 7a seems to show one or more attempted leaders preceding the leader to ground that start at second 53.87. The chi-square values for CGLSS and NLDN were good (0.7 and 2.0, respectively). The median (P = 0.50) semi-major axis (SMA) for CGLSS and NLDN were 0.18 nm and 1.7 km, respectively. The larger SMA for the NLDN network is expected, since the sensor spacing is roughly 10 times greater than CGLSS, and low-current strokes are typically seen by only 2-3 sensors. The location error for NLDN is evident in figure 7b, showing a separation of approximately 3.5 km. This difference is reasonable given the large NLDN SMA. The nearest previous flash occurred 226 km away and 03.736 seconds earlier.

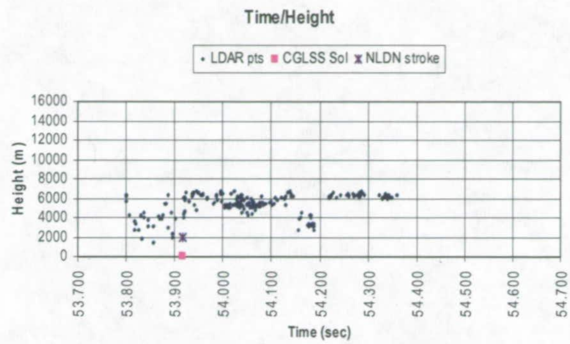

Figure 7a. Heights of LDAR sources as a function of time for a first stroke on July 17, 2006 at 19:46:53.9177 UTC with an Ip of -4.4 kA.

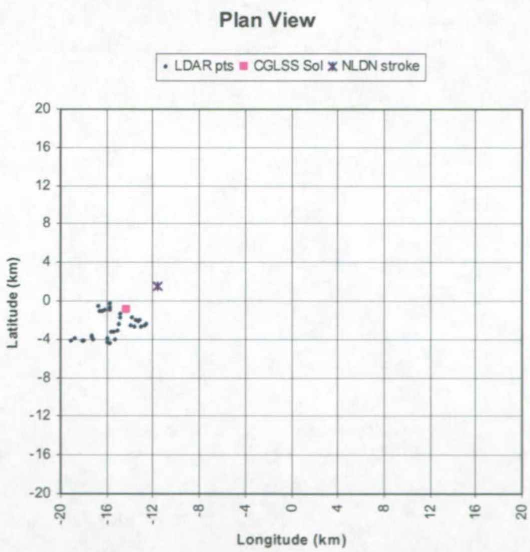

Figure 7b. Plan View of the LDAR sources and the CGLSS and NLDN stroke locations for the event shown in Figure 7a.

36 percent (41 strokes) of the stroke reports in our dataset were determined to be subsequent

strokes in a flash that produced a new ground contact (NGC). Figure 8 depicts a -4.7kA NCG stroke that occurred on July 23, 2006 at 21:13:10.0538 UTC. The time/height plot in Figure 8a shows a clear path to ground for the first stroke leader as well as the SoI. The NLDN did not detect the SoI, but did report a subsequent stroke down a PEC that preceded the SoI by 30 ms with an Ip of -24.4 kA. The chi-square value for the SoI was large, but acceptable (8.7) and the SMA was 0.37 nm. The NGC classification is evident in Figure 8b since the SoI occurred 4.78 km from the other strokes. As previously stated, a separation greater than 2km was the minimum distance criterion for a new CGLSS stroke report.

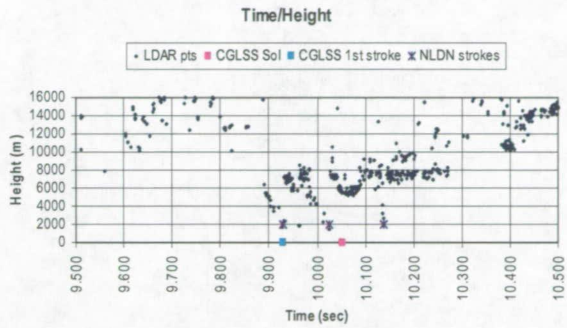

Figure 8a. Heights of LDAR sources as a function of time for a subsequent stroke that that produced a new ground contact on July 23, 2006 at 21:13:10.0538 UTC with an Ip of -4.7 kA.

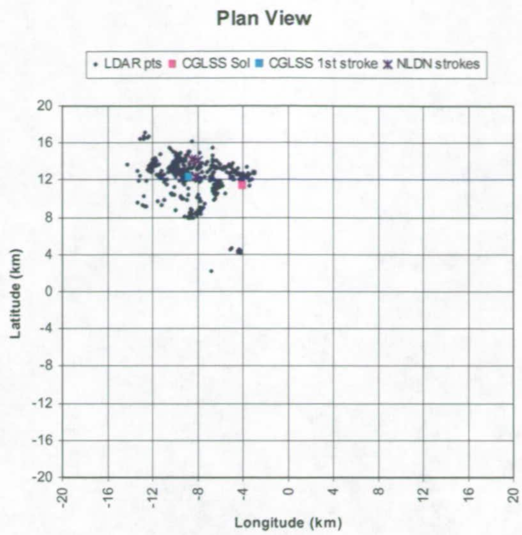

Figure 8b. Plan View of the LDAR sources and strokes shown in Figure 8a.

14 percent (16 strokes) of the strokes in our dataset were determined to be subsequent strokes in a flash that remained in a pre-existing channel (PEC). Figure 9 depicts a -4.3 kA stroke that remained in a PEC that occurred on July 7, 2006 at 19:11:53.6763 UTC. Like Figure 8a, the time/height plot in Figure 9a shows a clear path to ground for the first stroke leader but with no new leader pulses for the SoI. Although the NLDN detected the first stroke, it did not detect the low-current SoI. The chi-square value for CGLSS was high but acceptable (9.3) and the SMA for the CGLSS was 0.60 nm. The PEC classification in Figure 9b is due to the high chi-square and the short time-interval between the first stroke and SoI. This previous stroke occurred 00.027 seconds beforehand with a reported Ip of -11.2 kA.

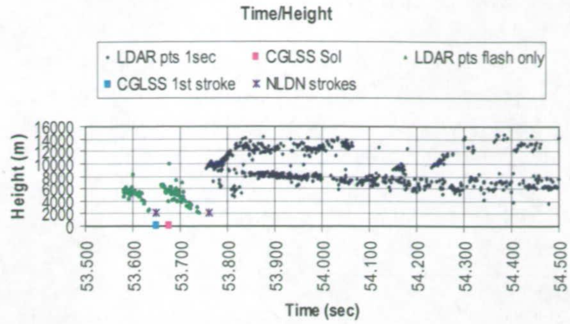

Figure 9a. Heights of LDAR sources as a function of time for a subsequent stroke in a flash that remained in a pre-existing channel on July 7, 2006 at 19:11:53.6763 UTC with an Ip of -4.3 kA.

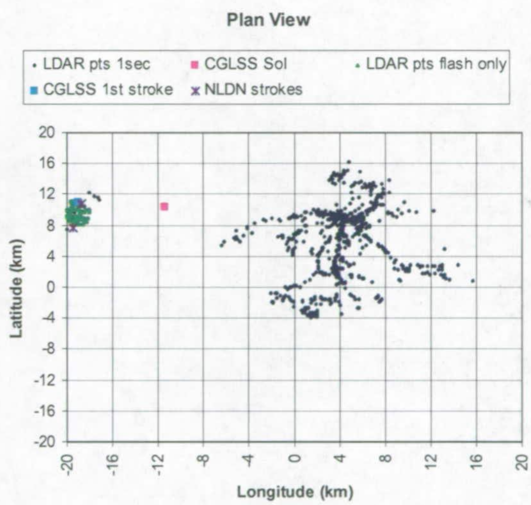

Figure 9b. Plan View of the LDAR sources and strokes shown in Figure 9a.

24 percent (27 strokes) of the strokes in our dataset were determined to be pulses in cloud discharges. Figure 10 depicts a -4.8 kA cloud pulse that occurred on July 7, 2006 at 18:46:39.5329 UTC. The time/height plot in Figure 10a shows that The LDAR sources have the characteristics of a classic cloud pulse. A cloud pulse will usually occur at the same time as a rapid upward leader occurs in the cloud. This is evident when the LDAR sources jump between 8,000m and 14,000m at the time of the CGLSS event. In this case, the CGLSS network could not determine a chi-squared value, so a value of 0 was recorded and the SMA was determined to be 0.37 nm. The NLDN network did not record this event and the nearest CGLSS stroke occurred 06.641 sec beforehand and was 40.4 km away.

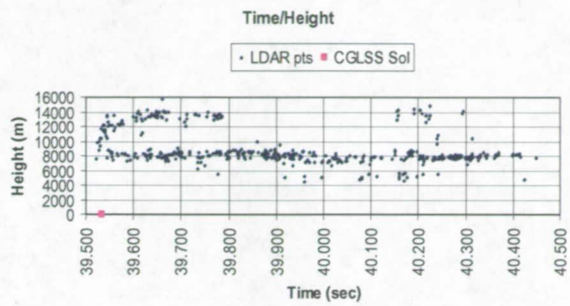

Figure 10a. Heights of LDAR sources as a function of time for a cloud pulse on July 7, 2006 at 18:46:39.5329 UTC with an Ip of -4.8 kA.

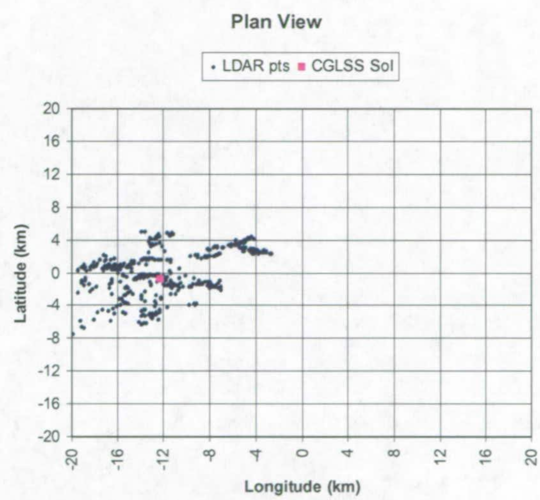

Figure 10b. Plan View of the LDAR sources shown in Figure 10a.

Minimum Inferred Peak Current

Of the 114 small strokes detected by CGLSS and LDAR that were studied in detail, -3.3 kA was the lowest Ip value for first strokes and -2.2 kA was the lowest Ip for a new ground contact. Table 1 in Appendix A shows a complete list of all results. Figure 11 is a histogram showing the distribution of Ip values for each type of ground stroke. The maroon bars show the values for

first strokes, the yellow bars show the number of strokes producing a NGC, and the green bars show the number of strokes that were in a PEC. It is important to note that 19 percent (or 15) of the strokes were less than -4.0 kA and, of these, 9 were new ground contacts, and only one, with an Ip of -3.3 kA, was a first stroke. 19 strokes were between -5.0 kA and -4.0 kA and of these 5 were first strokes.

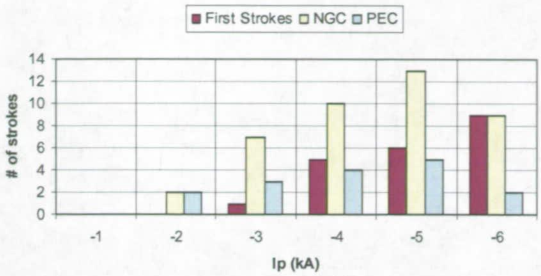

Figure 11. Distributions of the Ip values for low amplitude first strokes, strokes that produced a NGC, and strokes that remained in a PEC in 2006.

Figure 12 shows a similar distribution for the 27 cloud pulses that the CGLSS misclassified as a CG stroke as well as for the 9 events that we were not able to classify.

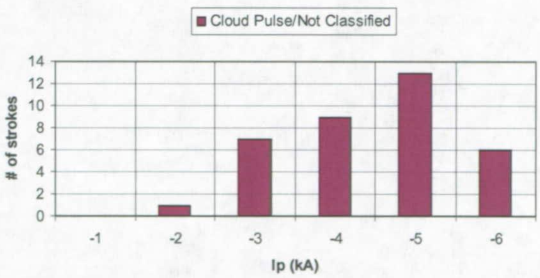

Figure 12. Distribution of Ip values for 27 misclassified cloud pulses and 9 events that could not be classified in 2006.

From these results, we can conclude that operationally one can see Ip values as small as -4 kA in first strokes and as small as -3 kA in the subsequent strokes that produce a new ground contact.

Discussion and Conclusions

Using the CGLSS network at the KSC-ER as the reference and the NLDN and LDAR systems for comparison, we have analyzed small negative stroke reports (i.e. strokes with an |Ip| < 7 kA) within 20 km of the LDAR central site to determine the type of lightning strokes that produced small peak currents during the summer of 2006. 21 (18%) of the 114 small negative stroke reports were determined to be for first strokes with no preference for production during small, large, or decaying storms. 57 (50%) strokes were produced by subsequent strokes that either created a new ground contact or remained in a preexisting channel. In all, we found that 78 (68%) of the small negative reports at the KSC-ER were produced by cloud-to-ground strokes. These findings are in good agreement with the results of Biagi et al. (2007) in AZ-TX-OK, except that Biagi et al. used an |Ip| ≤10 kA as the criterion for a small (negative) stroke and found that 50-87 % of the small NLDN reports could be classified as CG (either first or subsequent strokes) on the basis of video and waveform recordings. The final 36 reports (32%) in our dataset were likely cloud pulses or events that we were unable to classify. This work shows that the existing method employed by CGLSS to determine new ground strike points is somewhat flawed, in that about 1/7 of the return strokes occurred in pre-existing channels. A new CGLSS processing system (sensors will remain the same) is currently being certified for operational us at KSC-ER and should be operational by late January. This should address most of these existing problems.

The lowest Ip value for a first stroke was -3.2 kA, and the lowest value for subsequent strokes was -2.2 kA. This correlated well with (Rakov, 1985) who found a minimum Ip threshold of 2 kA for all negative CG's. When grouped into 1 kA bins (Figure 11), the number of low amplitude first strokes increased steadily between -3.2 kA and -7kA. These findings are also in agreement with existing literature stating that first strokes generally have larger peak currents than subsequent strokes, (Berger et al., 1975). Only one first stroke had an |Ip| < 4 kA but the number increased to 5 for |Ip| < 5 kA. This is consistent with observations by Berger for downward negative first stroke in tower lightning (Berger et al., 1975) where a minimum threshold of -5 kA was found.

Acknowledgement

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Appendix .
A list of 114 small negative lightning reports that had Ip …..

Table 1.

Date	Time	Ip	First Stroke	NGC	PEC	Cloud Pulse	unknown
7/7/2006	18:15:55.6837	-5				1	
7/7/2006	18:24:19.1153	-5.5				1	
7/7/2006	18:35:14.6537	-6.6	1				
7/7/2006	18:46:39.5329	-4.8				1	
7/7/2006	18:48:41.2102	-5.3		1			
7/7/2006	18:50:19.6226	-5				1	
7/7/2006	18:50:35.4982	-3.2					1
7/7/2006	18:54:36.6370	-3.5		1			
7/7/2006	18:54:48.6451	-5.7			1		
7/7/2006	18:56:35.3076	-5.6		1			
7/7/2006	18:59:51.3075	-4.5				1	
7/7/2006	19:03:13.1047	-6.4				1	
7/7/2006	19:03:27.8055	-3.5				1	
7/7/2006	19:03:56.2040	-6.3				1	
7/7/2006	19:05:17.0353	-4.7					1
7/7/2006	19:09:33.6853	-5.4				1	
7/7/2006	19:10:54.6326	-5.2		1			
7/7/2006	19:11:53.6763	-4.3			1		
7/7/2006	19:14:20.6099	-6.4				1	
7/7/2006	19:16:03.1608	-3.6		1			
7/7/2006	19:20:49.0701	-4.3	1				
7/7/2006	19:23:47.8382	-5.7	1				
7/7/2006	19:28:41.1213	-4.5				1	
7/7/2006	19:31:28.6916	-5			1		
7/7/2006	19:31:28.9872	-5.9	1				
7/7/2006	19:39:59.7074	-6.1				1	
7/7/2006	20:38:21.8335	-5.1				1	
7/17/2006	19:34:30.4315	-4.4		1			
7/17/2006	19:35:56.0584	-5			1		
7/17/2006	19:46:53.9177	-4.4	1				
7/17/2006	20:37:16.6092	-4.3	1				
7/17/2006	20:47:09.7348	-4.5	1				
7/17/2006	20:57:38.4864	-6.6	1				
7/18/2006	17:18:39.2573	-3.7			1		
7/18/2006	17:25:01.3361	-6.2		1			
7/18/2006	18:37:35.4248	-6.5	1				
7/18/2006	18:37:35.4642	-5.3	1				
7/23/2006	21:03:06.3785	-5.6		1			
7/23/2006	21:03:29.4811	-4.7		1			
7/23/2006	21:09:57.0712	-6.8			1		
7/23/2006	21:13:10.0538	-4.7		1			
7/23/2006	21:13:39.1120	-3.9		1			
7/23/2006	21:16:48.4687	-3.2					1
7/23/2006	21:21:23.4781	-4.6				1	
7/23/2006	21:21:42.6290	-6.2		1			
7/23/2006	21:21:53.0946	-5.7					1
7/23/2006	21:23:10.9802	-3.1			1		
7/23/2006	21:25:37.8282	-6.5			1		
7/23/2006	21:32:35.6353	-3.3	1				
7/23/2006	21:36:08.1579	-4.2			1		
7/23/2006	21:38:56.8712	-5.1					1
7/23/2006	21:46:12.3028	-4				1	
7/23/2006	21:59:26.1814	-6	1				
7/24/2006	19:51:47.6298	-6.6	1				
7/24/2006	19:54:34.3563	-4.7		1			
7/24/2006	19:59:43.6290	-4.3					1
7/24/2006	20:02:32.5285	-6.6		1			

Table 1 cont.

7/24/2006	20:05:49.0640	-5.7	1				
7/24/2006	20:12:44.0091	-5.8		1			
7/24/2006	20:14:58.0477	-3.7					1
7/24/2006	20:21:09.4709	-3.6		1			
7/24/2006	20:22:38.2109	-2.7			1		
7/24/2006	20:27:51.6043	-6.6		1			
7/31/2006	03:36:46.9772	-4.6			1		
7/31/2006	03:38:07.0818	-3.1				1	
7/31/2006	03:53:52.2343	-5				1	
7/31/2006	03:58:36.1581	-4.6		1			
7/31/2006	04:00:02.2818	-5.7	1				
7/31/2006	04:02:55.4583	-5.4			1		
7/31/2006	04:11:47.9123	-5.3			1		
7/31/2006	04:22:22.7304	-5.8		1			
8/23/2006	21:00:35.4450	-5.7		1			
8/23/2006	21:04:54.6026	-5.1		1			
8/23/2006	21:06:07.7543	-5.4		1			
8/23/2006	21:07:08.8205	-3.7			1		
8/23/2006	21:09:01.4893	-6.3				1	
8/23/2006	21:11:50.2856	-2.5			1		
8/23/2006	21:13:24.3781	-4		1			
8/23/2006	21:14:52.0391	-6.8		1			
8/23/2006	21:18:39.4184	-6.8		1			
8/23/2006	21:24:29.6247	-3.3		1			
8/23/2006	21:27:26.9475	-2.2		1			
8/23/2006	21:30:18.8479	-5.7		1			
8/23/2006	21:32:17.8209	-3.4				1	
8/23/2006	21:32:23.7410	-3.3		1			
8/23/2006	21:33:51.2705	-2.9				1	
8/23/2006	21:34:48.6330	-6.2				1	
8/23/2006	21:35:47.3809	-5.8				1	
8/23/2006	21:37:04.1037	-5.4		1			
8/23/2006	21:38:50.5521	-6.4		1			
8/23/2006	21:39:20.8081	-4.9				1	
8/23/2006	21:42:39.9120	-6.6		1			
8/23/2006	21:46:14.9026	-4.5				1	
8/23/2006	21:57:23.3923	-3.3		1			
8/23/2006	21:59:51.8961	-3.6				1	
8/23/2006	21:59:58.4188	-4.6			1		
8/23/2006	22:00:31.1009	-2.9		1			
8/23/2006	22:05:41.5598	-4.5		1			
8/23/2006	22:08:22.5453	-4.2		1			
8/23/2006	22:09:22.7297	-5.4					1
8/23/2006	22:11:26.1130	-5.5		1			
8/23/2006	22:13:17.5709	-4.8		1			
8/23/2006	22:20:36.2522	-6.6	1				
8/23/2006	22:20:36.3703	-6	1				
8/23/2006	22:25:23.0534	-4.2		1			
8/23/2006	21:34:24.3374	-5.2					1
8/26/2006	19:17:25.5023	-6.6	1				
8/26/2006	19:19:07.7613	-5.5				1	
8/26/2006	19:21:55.3174	-6.8	1				
8/26/2006	19:22:40.0868	-6.7		1			
8/26/2006	19:30:08.6249	-5				1	
8/26/2006	19:52:39.2567	-5.1	1				
8/26/2006	19:54:07.8857	-5.8		1			
8/26/2006	20:57:38.7088	-4.8	1				
totals			21	41	16	27	9